AAE 507: Principles of Dynamics

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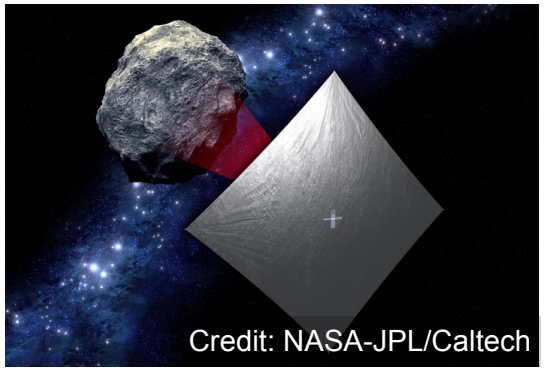
Why do we learn dynamics?

Dynamics: fundamental to modeling, analysis, design, navigation, and control of *any* space systems

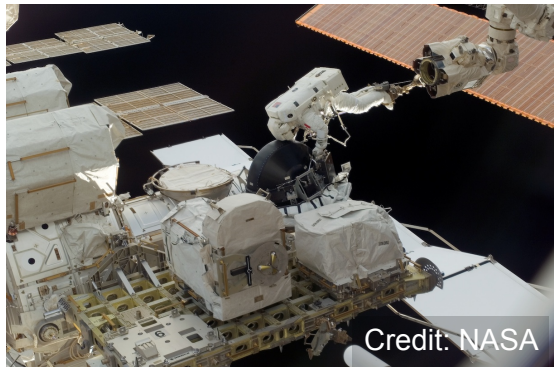
Multi-body orbital dynamics
(e.g., cislunar space)

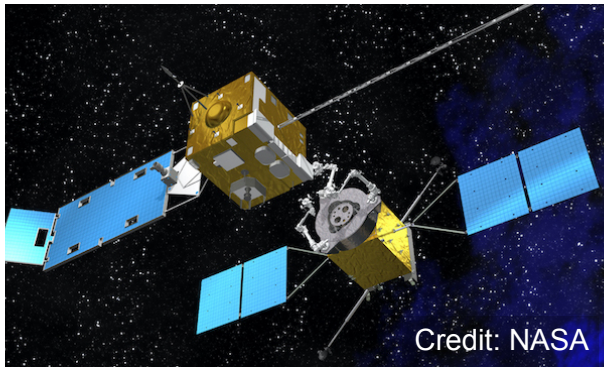
Perturbed orbital dynamics
(e.g., asteroid exploration)



Attitude-orbit coupled dynamics
(e.g., solar sails, tethered satellite)

Attitude dynamics
(e.g., control moment gyros on space station)

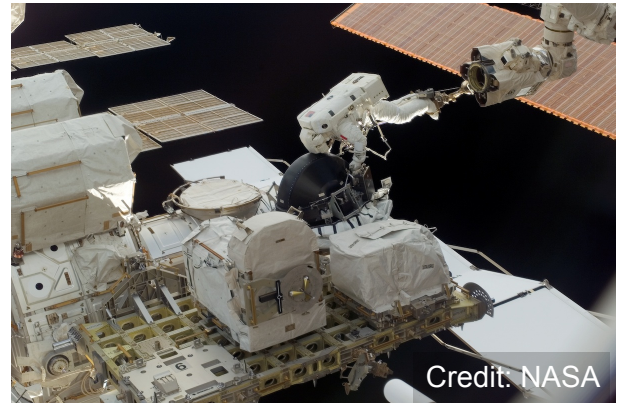




6-DoF control
(e.g., on-orbit servicing, proximity operation)

Why analytical mechanics?

- Familiar Newton-Euler mechanics:
  - Rely on calculating force and moment balances
  - Fully valid, but can be *cumbersome* for complex systems (e.g., attitude dynamics with many momentum-exchange devices or flexible structures, orbital dynamics analysis in different coordinates, …)
- Analytical mechanics:
  - Provide systematic language and mathematical tools for dynamics modeling and analysis
  - **Lagrangian mechanics**: equations of motion from energy
  - **Hamiltonian mechanics**: describe dynamics in phase space and reveal its underlying structure and geometry
  - extend naturally to perturbation methods, numerical methods, trajectory design, and optimal control


Credit: NASA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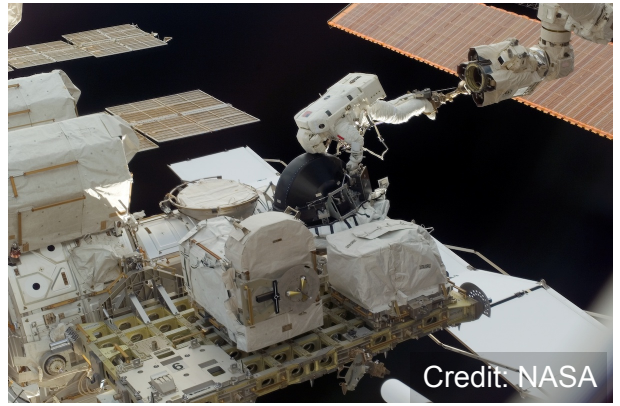
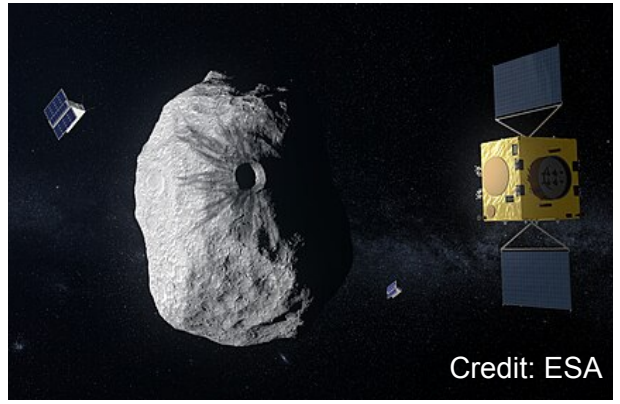
Principles of Dynamics — Learning Goals:

- Acquire fundamental knowledge of analytical mechanics, including the Lagrangian and Hamiltonian mechanics
- Apply variational principles, generalized coordinates, phase-space concepts, canonical transformations, and conservation laws to analyze dynamical systems
- Formulate equations of motion for mechanical and aerospace systems using Lagrangian and Hamiltonian methods
- Develop original computing scripts using a programming language to numerically simulate and analyze nonlinear dynamical systems
- Present and communicate their technical approaches to given problems, their analytical/numerical results, and their interpretation in a written format


Credit: NASA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